CHAPTER 4

PROPOSED MOBILITY MANAGEMENT TECHNIQUES FOR CALLS FROM FIXED LINE TO MOBILE STATION IN ROAMING MODE

4.1 Introduction

There were two types of cellular systems. They are analog cellular systems and digital cellular systems. In analog cellular systems, it is difficult to augment capacities of the networks due to their interference characteristics. However, in the case of digital cellular networks, this problem is not present. By adding new cells and splitting the existing cells, it is possible to increase the capacity of mobile networks.

The advantages of digital cellular systems are that it is easy to increase capacity. This capacity can be of large multiples when compared to those of analog cellular systems. The power consumed will be less and the life of battery is more. It is possible for the MS to roam across the globe and still be in the network [Raj Pandya, 2000]. There is increased security with the encryption of data that traverses across the network. Also, there is no restriction on the size of the cells. Hence, it is possible to offer mobile services in any cell irrespective of its size.

The most important elements of the GSM system are MS, BTS, BSC, MSC, HLR and VLR. Together, BTS and BSC form part of BSS. Usually, the path of communication includes all the above mentioned elements starting from MS or the device from where the call has originated. When the call originates from the MS, the path continues to BSS to MSC to VLR to HLR and so on [Fraidoon Mazda, 1998]. The path is different depending on the device from where the call has originated and
where the call has terminated.

In the case of roaming, HLR is accessed for setting up the call. This consumes precious network resources and increases the path to set up call. However, by including additional elements into the network, it is possible to skip querying HLR thus reducing the call set up path. It also leads to the reduced consumption of network resources. In this chapter, techniques were proposed for different scenarios where the need to access HLR is eliminated. The inclusion of two elements into GSM network, namely, THLR and AHLR is herewith proposed. Also, each technique is followed by implementation diagram.

In this chapter, the existing algorithm for mobile call termination in the case where the call has originated from a fixed line is presented. MS to which the call has been made by fixed line is in roaming mode. The existing algorithm is followed by two cases. In the first case, MS is in the same network as that of fixed line, but in roaming mode. In the second case, MS is in the network adjacent to that of fixed line, but in roaming mode. X1, X2 an X3 are networks. Each algorithm is followed by an implementation diagram and a location update procedure.

4.2 Proposed structure of THLR

It is hereby proposed to have a THLR in every cell. The proposed structure of THLR is as shown in figure 4.1.

<table>
<thead>
<tr>
<th>IMSI</th>
<th>MSISDN</th>
<th>Visiting MSC/VLR</th>
<th>CMS</th>
<th>MES</th>
<th>GPRS</th>
<th>Billing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 16</td>
<td>30 31</td>
<td>45</td>
<td>46</td>
<td>47</td>
<td>48  49</td>
</tr>
</tbody>
</table>

Figure 4.1: Structure of THLR

THLR is having following fields [Venkata Suresh Pachigolla et al., 2010]:

79
- IMSI //Maximum:15 characters
- MSISDN //Maximum: 15 characters
- Visiting MSC/VLR //Maximum:15 characters
- CMS //Boolean Value
- MES // Boolean Value
- GPRS // Boolean Value
- Billing // Number

THLR will have information of all MSs which are in roaming mode in the respective cell.

### 4.3 Proposed structure of AHLR

It is hereby proposed to have an AHLR in every cell. The proposed structure of AHLR is as shown in figure 4.2.

<table>
<thead>
<tr>
<th>IMSI</th>
<th>MSISDN</th>
<th>Visiting MSC/VLR</th>
<th>CMS</th>
<th>MES</th>
<th>GPRS</th>
<th>Billing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15 16</td>
<td>30 31</td>
<td>45</td>
<td>46</td>
<td>47</td>
<td>48</td>
</tr>
</tbody>
</table>

Figure 4.2: Structure of AHLR

AHLR is having following fields [Venkata S Pachigolla et al., 2011]:

- IMSI //Maximum:15 characters
- MSISDN //Maximum: 15 characters
- Visiting MSC/VLR //Maximum:15 characters
- CMS //Boolean Value
- MES // Boolean Value
- GPRS // Boolean Value
- Billing // Number
AHLR will have information of all MSs which are in roaming mode in cells that are adjacent to the cell in which it was present.

4.4 Fixed Line to Mobile Station Communication

This section focuses on algorithms that are related to communication between fixed lines and MSs. It is assumed that the host network of the callee MS is not adjacent to the network of the fixed line which is caller.

4.4.1 Algorithm-1

The following is the existing algorithm (algorithm-1) for mobile call termination when the caller is a fixed line and the callee is a MS in roaming mode [Raj Pandya, 2000]:

1. Start
2. Dial the mobile number from fixed line
3. The call goes to LTE i.e. PSTN (a)
4. LTE finds that the dialled number is a mobile number belonging to external network and forwards it to GMSC (b)
5. GMSC contacts the HLR of the service provider and sends the mobile number(c)
6. HLR will communicate with serving VLR of the MS (d)
7. VLR will communicate information about serving MSC of MS to HLR (e)
8. HLR forwards that information to GMSC (f)
9. GMSC routes call to serving MSC (g)
10. MSC finds the current LAI of MS from VLR (h)
11. MSC pages the MS through appropriate BSS (j, k)
12. MS responds (l)

13. BSS confirms to MSC that the necessary radio links are established (m)

14. Call is delivered to MS

15. When MS answers, complete call is set up

16. End of Algorithm

4.4.2 Implementation Diagram for Algorithm-1

Figure 4.3 depicts the implementation diagram for the algorithm (algorithm-1) mentioned in section 4.4.1.

![Implementation Diagram for Algorithm-1](image)

Figure 4.3: Implementation diagram (Algorithm-1)

The call setup path is $a \rightarrow b \rightarrow g \rightarrow j \rightarrow k$

4.4.3 Location Update Procedure for Algorithm-1

It is assumed that the MS whose host network is X3 moved from X1 to X2. Then, it makes a location update request to VLR(new) through BSS(new) and MSC(new). The VLR(new) sends a location update message to HLR in X3. The service and security
related data for the MS is downloaded to the VLR(new) from HLR. The MS is sent an acknowledgement of successful location update. The HLR requests VLR(old) to delete data relating to the relocated MS[Bud Gates, 1995].

The GMSC of the fixed line always connects to HLR of the dialled mobile number by the fixed line. For that reason, it’s arrow is left open ended. Figure 4.4 depicts the location update procedure for Algorithm-1. MS moves from X1 to X2. It’s HLR is located in X3.

The following is the location update procedure for algorithm-1:

1. Start
2. MS whose HLR is in X3 moves from X1 to X2
3. It contacts the BSS (new) in X2 for resource allocation (a)
4. BSS(new) contacts MSC(new) for resource allocation (b)
5. MSC(new) contacts VLR(new) for resource allocation (c )
6. VLR(new) contacts HLR of MS in X3 for information about MS (d)
7. HLR updates the location of MS in its database and then sends requisite information to VLR (new) (e)

8. VLR (new) forwards the information to MSC(new) (f)

9. MSC (new) forwards the information to BSS(new) (g)

10. BSS (new) communicates to MS that the necessary resources are allocated (h)

11. HLR communicates to VLR(old) that it may delete entry corresponding to MS(i)

12. End of Algorithm

### 4.4.4 Proposed Algorithm-2

The following is the proposed algorithm (algorithm-2) for mobile call termination when the caller is a fixed line and the callee is a MS in roaming mode [Venkata Suresh Pachigolla et al., 2010]. This algorithm deals with the case when both caller and callee are in the same network:

1. Start

2. Dial the mobile number from fixed line

3. The call goes to LTE i.e. PSTN (a)

4. LTE finds that the dialled number is a mobile number belonging to external network and forwards it to GMSC (b)

5. GMSC contacts the THLR of the service provider and sends mobile number(c)

6. THLR will communicate with serving VLR of the MS (d)

7. Serving VLR will communicate information about serving MSC of MS to THLR (e)

8. THLR forwards that information to GMSC (f)
9. GMSC routes call to serving MSC (g)

10. Serving MSC finds the current LAI of MS from VLR (h)

11. Serving MSC pages the MS through appropriate BSS (j, k)

12. MS responds (l)

13. BSS confirms to MSC that the necessary radio links are established (m)

14. Call is delivered to MS

15. When MS answers, complete call is set up

16. End of Algorithm

### 4.4.5 Implementation Diagram for Algorithm-2

Figure 4.5 depicts the implementation diagram for proposed algorithm (algorithm-2) mentioned in section 4.4.4. [Venkata Suresh Pachigolla et al., 2010].

![Implementation Diagram](image)

The advantage of the proposed algorithm-2 is that if the called mobile is within the caller’s network in roaming mode, then the call will be routed through
THLR rather than HLR. So, the call becomes a local call rather than a call to external network.

The disadvantage of the proposed algorithm-2 is that if the called mobile is not found in THLR, then it has to go to AHLR. If the called mobile number is not found in AHLR also, then it has to go to HLR. So, in this case, the complexity is more by $O((\text{size of THLR}) + (\text{size of AHLR}))$.

The call setup path is $a \rightarrow b \rightarrow g \rightarrow j \rightarrow k$

4.4.6 Location Update Procedure for Algorithm-2

In a system where THLR is present, when MS (whose HLR is in X3) moves from X1 to X2, then MS makes a location update request to VLR(new) through BSS(new) and MSC(new). The VLR(new) sends a location update message to HLR in X3. The service and security related data for the MS is downloaded to the VLR(new) of the HLR. The VLR(new) will create a mirror entry for MS in THLR of X2 so that any more calls to MS from any fixed line in X2 need to only look at THLR in X2 and need not query HLR in X3. The HLR in X3 will request VLR(old) to remove information about MS. The VLR(old) in turn will alert THLR in X1 to delete entry about MS. Figure 4.6 depicts the location update procedure for proposed algorithm-2 [Venkata Suresh Pachigolla et al., 2010].

![Figure 4.6: Location update procedure (Algorithm-2)](image)
The following is the location update procedure for proposed algorithm-2 [Venkata Suresh Pachigolla et al., 2010]:

1. Start

2. MS whose HLR is in X3 moves from X1 to X2

3. It contacts the BSS(new) in X2 for resource allocation (a)

4. BSS(new) contacts MSC(new) for resource allocation (b)

5. MSC(new) contacts VLR(new) for resource allocation (c)

6. VLR(new) contacts HLR of MS in X3 for information about MS (d)

7. HLR updates the location of MS in its database and then sends requisite information to VLR(new) (e)

8. VLR(new) updates THLR in X2 as MS is currently in X2 in roaming mode (f)

9. VLR(new) forwards the information to MSC(new) (g)

10. MSC(new) forwards the information to BSS(new) (h)

11. BSS(new) communicates to MS that the necessary resources are allocated (i)

12. HLR communicates to VLR(old) that it may delete entry corresponding to MS (j)

13. VLR(old) communicates to THLR of X1 to delete entry corresponding to MS (k)

14. End of Algorithm

4.4.7 Proposed Algorithm-3

Consider two networks X1 and X2 which belong to two states that border each other.
Host networks of two states which border each other make up a very good example. Also, consider a network X3 which does not have X1 and X2 as its borders. If a fixed line in X2 calls MS which is in X1, but whose host network is X3, then the HLR of MS in X3 is contacted though the MS is present in X1 which is bordering X2.

Note that the MS is currently in roaming mode. It should also be assumed that the distance between X1 and X2 is less in comparison to X1 and X3. Conventionally, the algorithm-1 mentioned in section 4.4.1 is applied when the fixed line in X2 calls MS in X1 in roaming mode but belongs to X3.

An algorithm (algorithm-3) which will ensure that the GMSC will not contact HLR of MS if MS is in a network that is adjacent to its network is herewith proposed.

The following is the proposed algorithm (algorithm-3) for mobile call termination [Venkata S Pachigolla et al., 2011]:

1. Start
2. Dial the mobile number from fixed line
3. The call goes to LTE i.e. PSTN (a)
4. LTE finds that the dialled number is a mobile number belonging to external network and forwards it to GMSC (b)
5. GMSC contacts the THLR of the service provider and sends the mobile number (c)
6. However, mobile number of MS will not be found in THLR as it is not present in X2.
7. So, THLR queries AHLR (d)
8. AHLR will communicate with serving VLR of the MS (a)
9. Serving VLR will communicate information about serving MSC of MS to
10. AHLR forwards that information to GMSC (g)

11. GMSC routes call to serving MSC (h)

12. Serving MSC finds the current LAI of MS from VLR (i)

13. Serving VLR sends LAI to serving MSC (j)

14. Serving MSC pages the MS through appropriate BSS (k, l)

15. MS responds (m)

16. BSS confirms to MSC that the necessary radio links are established (n)

17. Call is delivered to MS (k, l)

18. When MS answers, call set up is done (m)

19. End of Algorithm

**4.4.8 Implementation Diagram for Algorithm-3**

Figure 4.7 depicts the implementation diagram for proposed algorithm-3 mentioned in section 4.4.7. [Venkata S Pachigolla et al., 2011].
This algorithm leads to benefit to all adjacent networks of the network in which a MS is roaming so that the adjacent networks need not contact the HLR of the MS in the host network.

The call setup path is \( a \rightarrow b \rightarrow h \rightarrow k \rightarrow l \)

### 4.4.9 Location Update Procedure for Algorithm-3

In this model, when MS moves from X1 to X2, the VLR(new) on receiving information from HLR in X3 will pass that information to THLR in X2. After receiving command to delete information from HLR, the VLR(old) will request for deletion of information about MS from THLR in X1. THLR in X1 will request all AHLRs to delete information about MS. Figure 4.8 depicts the location update procedure for proposed algorithm-3 [Venkata S Pachigolla et al., 2011].

The following is the location update procedure for proposed algorithm-3 [Venkata S Pachigolla et al., 2011]:

1. Start

2. MS whose HLR is in X3 moves from X1 to X2
3. It contacts the BSS(new) in X2 for resource allocation (a)

4. BSS(new) contacts MSC(new) for resource allocation (b)

5. MSC(new) contacts VLR(new) for resource allocation (c)

6. VLR(new) contacts HLR of MS in X3 for information about MS (d)

7. HLR updates the location of MS in its database and then sends requisite information to VLR(new) (e)

8. VLR(new) updates THLR in X2 as MS is currently in X2 in roaming mode (f)

9. VLR(new) forwards the information to MSC(new) (g)

10. MSC(new) forwards the information to BSS(new) (h)

11. BSS(new) communicates to MS that the necessary resources are allocated (i)

12. HLR communicates to VLR(old) that it may delete entry corresponding to MS (j)

13. VLR(old) communicates to THLR of X1 to delete entry corresponding to MS (k)

14. THLR of X1 communicates to AHLR of X2 to delete entry corresponding to MS (l)

15. THLR of X2 communicates the information about MS to AHLR of X1 so that it can add suitable entry about MS (m)

16. End of Algorithm

4.5 Results

In this section, it shall be proved that the proposed algorithms possess reduced complexity when compared to existing algorithms. The proof is based on weighing parameters assigned for communications between different nodes in the respective
network. When a node communicates to another node in the same network, the communication is assigned a weightage of 1. If a node communicates to another node in an adjacent network, the communication is assigned a weightage of 2. If a node communicates to any other node which is neither in the same network nor in adjacent network, then, then the communication is assigned a weightage of 3.

A communication system which results in less total weightage is efficient when compared to communication systems which result in more total weightage for reaching destination from source. Programs are written in ‘C’ language for the implementation of the algorithm-1, algorithm-2 and algorithm-3 discussed in the above sections. The programs print weightage tables and the total weightage.

4.5.1 Total weightage for Algorithm-1

Figure 4.9 depicts the screen shot of the output of the program that implemented the existing algorithm-1 as per implementation diagram given in figure 4.3.
It was assumed that the host network X2 of the MS which is a callee in roaming mode in X1 is not adjacent to X1. The total weightage for existing algorithm-1 is found to be 19.

4.5.2 Total weightage for proposed Algorithm-2

Figure 4.10 depicts the screen shot of the output of the program that implemented the proposed algorithm-2 as per implementation diagram given in figure 4.5.
The total weightage for proposed algorithm-2 is found to be 11 which is less than the total weightage of the existing algorithm-1 whose weightage is 19. This algorithm dealt with the case where the callee MS is in roaming mode in the same network X1 as that of caller. It was assumed that the host network X2 of the MS which is a callee in roaming mode in X1 is not adjacent to X1.

**4.5.3 Total weightage for proposed Algorithm-3**

Figure 4.11 depicts the screen shot of the output of the program that implemented the proposed algorithm-3 as per implementation diagram given in figure 4.7.
The total weightage for proposed algorithm-3 is found to be 15 which is less than the total weightage of the existing algorithm-1 whose weightage is 19. This algorithm dealt with the case where the callee MS is in roaming mode in an adjacent network X1 to that of caller’s X2.

4.6 Chapter Summary

In this chapter, the existing algorithm-1 for call setup from a fixed line to a MS which
is in roaming mode in the same network as that of caller is given. Along with the
algorithm-1, implementation diagram and location update procedure were also given.
It was followed by two proposed algorithms 2 and 3.

The first proposed algorithm-2 dealt with call setup from fixed line to MS
which is in roaming mode in the same network as that of caller. However, the call
setup does not involve contacting HLR which is the reason for reduced call setup
path. The trade off is the introduction of THLR into the GSM network. The second
proposed algorithm-3 dealt with call setup from fixed line to MS which is in roaming
mode in an adjacent network as that of caller. However, the call setup does not
involve contacting HLR which is the reason for reduced call setup path. The trade off
is the introduction of THLR and AHLR into the GSM network.

The total weightages calculated for the proposed algorithm-2 and proposed
algorithm-3 to setup call are found to be 11 and 15 which are less than the total
weightage calculated for the existing algorithm-1 which is 19. Hence, it can be
concluded that the proposed algorithm-2 and proposed algorithm-3 are efficient when
compared to the existing algorithm-1.